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MODÈLES DYNAMIQUES EN BIOLOGIE, R. ARDITI (DIR.)
DYNAMICAL MODELS IN BIOLOGY, R. ARDITI (ED.)

Résumés - Abstracts

Sergio RINALDI¹. Structural properties of controlled population models².

The classical Leslie model used for describing the natural growth of age-structured populations is adapted to the case of controlled populations. Such a model is a nonlinear positive system with non-negative inputs and enjoys remarkable structural properties. The non-trivial equilibria are critically stable but can be stabilized by a state viable feedback. The set of states reachable from any given initial state is a positive cone generated by n reachability vectors $b, Ab, \dots, A^{n-1}b$. The system is completely observable and its state can be reconstructed provided the input sequence can be suitably programmed. All these properties constitute an important theoretical framework for population control problems.

Roger ARDITI³. Coupling in predator-prey dynamics: ratio-dependence⁴.

In continuous-time predator-prey models, the *per capita* rate of consumption (the functional response or «trophic function») is usually interpreted as a behavioral phenomenon. The classical assumptions are that predators encounter prey at random and that the trophic function depends on prey abundance only. We argue that this approach is not always appropriate. The trophic function must be considered on the slow time scale of population dynamics at which the models operate – not on the fast behavioral time scale. We propose that, in cases where these two time scales differ, it is reasonable to assume that the trophic function depends on the *ratio* of prey to predator abundances. Several field and laboratory observations support this hypothesis. We compare the consequences of the two types of dependence with respect to the dynamical properties of the models and the responses of population equilibria to variations in primary production. In traditional prey-dependent models, only the predator population responds to primary production, while both levels

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⁴Paper published by R. ARDITI and L.R. GINZBURG, 1989. *Journal of Theoretical Biology* 139: 311-326.

respond in ratio-dependent models. This result is generalized to food chains. We suggest that the ratio-dependent form of the trophic function is a simple way of accounting for many types of heterogeneity that occur in large scale natural systems, while the prey-dependent form may be more appropriate for homogeneous systems like chemostats.

Marino GATTO¹. Physiological profiles and demographic rates in relation to food quantity and predictability: an optimization approach².

A model is developed which, starting from assumptions about an organism's basic physiology, produces (age-independent) fertility and mortality rates, and therefore the population rate of increase, as functions of the amount of food available in the environment. These rates depend, among other things, on the organism's «life-strategy», which consists of: (i) a food allocation policy, i.e. a function of food availability which determines the proportion of food energy allocated to self maintenance and to reproduction respectively; (ii) offspring size at the moment of independence, which also may vary with food abundance. Food related mortality is modelled as a consequence of starvation faced by some individuals, due to local food shortages caused by short-term fluctuations in the environment. Along with demographic rates we also derive, as functions of food availability, the amount of biomass invested in vegetative (body size) and reproductive structures respectively. Thus, to a «life-strategy» there corresponds a whole physiological and demographic profile, i.e. a pattern of variation of: food allocation, offspring size, body size, fertility and mortality, in relation to changes of food abundance.

Based on a criterion of evolutionary stability, which is valid with both density-independent and density-dependent population dynamics, we determine optimal (ESS) «life-strategies» for a large class of examples. The associated profiles can be clustered around three qualitatively distinct typologies: the «spendthrift», the «saver» and the «investor», in which the conflicting goals of reproduction and self-preservation are differently emphasized. The spendthrifts' strategy devotes all the energy in excess of pure maintenance to reproduction, regardless of food availability. On the contrary, the savers' and the investors' strategies are characterized by a threshold of food abundance, below which no reproduction takes place and all food intake is allocated to maintenance and body growth. Above the threshold, however, the saver maintains a constant body size and devotes all energy surplus in part to reproduction and in part to further growth.

Which strategy is optimal depends upon: (i) habitat characteristics tied to predictability of the food supply, i.e. frequency and duration of food shortages; (ii) properties of the organism's feeding physiology as summarized by feeding efficiency, a unimodal function of body size which measures return in feeding activity per unit investment in metabolic rate. In particular, the spendthrifts' strategy is optimal in habitats with rare but long periods of food deprivation, while savers prevail in habitats with frequent but short starvation episodes. However, very narrow feeding efficiency functions, i.e. very narrow ranges of efficient body sizes, tend to favour the spendthrifts' strategy irrespective of food predictability. Very broad feeding efficiency functions, instead, imply optimality of the investors' strategy.

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²Paper published by M. GATTO, C. MATESSI and L.B. SLOBODKIN, 1989. *Evolutionary Ecology* 3: 1-30.

Mark A. BURGMAN¹. A stage-structured, stochastic population model for the giant kelp *Macrocystis pyrifera*².

We have developed a population model for giant kelp, *Macrocystis pyrifera*, in southern California. The model includes five life-history stages and takes into account environmental and demographic stochasticity, as well as density-dependent interactions. The density of each stage is predicted on a monthly basis for up twenty years, and extinction probability is determined for adult sporophytes. Survival probabilities and rates of reproduction and growth are based on stage specific responses to environmental conditions (irradiance and temperature), including the occurrence of El Niño events. The model is validated by comparing simulation results to empirical data from natural kelp populations. Results of the model provide insight into patterns observed in natural populations and have applications in resource management.

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² Paper to be published by M.A. BURGMAN and V.A. GERARD in *Marine Biology*.

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